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ELECTROMAGNETIC INTERFERENCE DESIGN AND TEST CRITERIA, DYNA-SOAR (620A)

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AD

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1.0 REFERENCES

1.1 Military publications

1.1.1 Statement of Work, System 620A, Dyna Soar (Step I), Exhibit 620A-60-14A, dated 6 August 1960, revised 1 November 1960.

1.1.2 MIL-I-26600 (USAF) (rev. June 2, 1958) Interference Control Requirement, Aeronautical Equipment

1.1.3 ARDC Manual 80-5, Handbook of Instructions for Ground Equipment Designers.

1.1.4 ARDC Manual 80-6, Handbook of Instructions for Aircraft Ground Equipment Designers.

1.1.5 MIL-E-4158B (January 3, 1958) Electronic Equipment, Ground, General Requirements.

1.1.6 MIL-S-8512B (January 8, 1958) Support Equipment, Aeronautical, Special: General Specification for the design of

1.1.7 MIL-B-5087A, Bonding; (for Aircraft).

1.2 Boeing publications

1.2.1 D-18306, Magnetic and electrostatic wire coupling in the audio frequency range.

2.0 INTRODUCTION

2.1 This document sets forth the design criteria and interference control plans to be employed in assuring elimination or satisfactory suppression of radio interference in the Dyna Soar System as required by MIL-I-26600 and para. B(1.1.3.8)2 of Ref. 1.1.1.

2.2 Additions and/or corrections may be made to this document at any time to reflect the latest design and test plans as the Dyna Soar program progresses.

2.3 Deviations from the requirements of specification MIL-I-26600 have not been requested pending determination of the specification adequacy as determined by comparison with techniques evolved for solution of Dyna Soar problems.

It is current policy that no requests for deviations to the provisions of MIL-I-26600 will be entertained except in the following areas:

(a) Expansion of MIL-I-26600 to cover frequency ranges or techniques not currently covered by the specification, and

(b) Exceptions taken to MIL-I-26600 provisions for short-time use of equipment which is non-tactical and is neither a prototype nor an evolutionary forerunner of a tactical equipment. Exceptions must be applied for and will be granted on an individual basis only after careful consideration of the effects of the equipment utilization.

3.0 SUMMARY

3.1 Reduction of electromagnetic interference in the Dyna-Soar System shall be accomplished by

(a) Use of low-noise design techniques and component parts together with adequate shielding and filtering, bonding and grounding to lower interfering outputs and reduce susceptibility to interference sources;

(b) Avoidance of undesired resonances with fundamentals, harmonics and products of known radio frequency sources within the Dyna-Soar System;

(c) Determination of interference problem areas in advance of system integration by interference control at the lowest sub-assembly levels capable of sustaining meaningful interference testing.

3.2 Interference testing shall be conducted as described in Section 5 of this document to insure compliance of the several portions of the Dyna-Soar System with required standards and specifications.

It is intended that Section 5 be expanded to provide detailed test plans for Dyna-Soar systems, sub-systems and elements requiring interference control measurements.

These detailed test plans will be prepared and included by revision to this document as the equipment details are defined.

4.0 DESIGN CRITERIA

4.1 General Practices

4.1.1 Design Objectives

The design objectives of electromagnetic interference control are to eliminate or satisfactorily suppress all forms of electromagnetic interference at their sources and to eliminate or adequately minimize the susceptibility of equipment sensitive to electromagnetic disturbances. The design of the entire system complex shall be such that generation, conduction, radiation and coupling of any spurious emissions will be considered in all cases and will be held to the minimum practicable levels.

4.1.2 Subsystems and Systems

The basic subsystems and systems of the Dyna-Soar complex shall be designed so that each is neither a source of nor is susceptible to electromagnetic interference within the limits of MIL-I-26600 as delineated in Section 5 of this document.

All sources of RF or pulse power shall be shielded and filtered appropriately to prevent unwanted escape of energy. All non-signal leads shall be filtered and the shielding used shall be continuous and coherent. Powerful sources of energy shall use shielding thickness appropriate to the electromagnetic levels involved and careful attention shall be given to shield connections for avoidance of electromagnetic pickup loops in shielding circuits.

Amplifiers, tuners, IF strips and other susceptible items shall be treated in similar fashion; tightly shielded and filtered to prevent entrance of interference. All non-signal leads shall be filtered and signal circuits, where possible, shall be restricted to the necessary pass band.

4.1.3 Components

Components of the various subsystems and systems shall be chosen from among those which have the least probability of generating or being susceptible to electromagnetic disturbances, consistent with the primary application.

4.1.4 Filtering

Lead filtering shall be added to an installation, not as a panacea for all interference problems, but only after careful design has minimized the generation of interference. Such filters prevent distribution of noise on inter-unit conductors and should be physically located as near the noise source as layout permits to reduce radiation from unfiltered wiring. Relay contacts and other switching or commutating devices shall be transient-suppressed, particularly when switching relay coils or other inductive loads, by appropriate filter networks.

4.1.5 Shielding

Electrical and electronic wiring and circuitry which could be either a source of or susceptible to electromagnetic interference shall be shielded, with shield grounds located to make the shielding most effective. All antenna leads shall be waveguide or coaxial cable. Wherever high power or sensitive circuitry is involved, multiple shielded coaxial cable shall be used to prevent mutual coupling.

Integrity of enclosure shielding shall be maintained by use of bonding, metallic weatherstripping, and/or other techniques which have been developed for this purpose.

4.1.6 Antenna Systems

Antenna Systems, including Multiplexers and other feed networks, shall be designed for a minimum of signal cross-coupling consistent with other requirements.

It should be noted that transmitters employing Class C and overbiased Class B amplifiers in the output stage are essentially non-linear devices and are capable of being modulated by any voltages appearing in their input or output circuits. It is extremely important, therefore, that sufficient decoupling and filtering be incorporated into the design of output networks for such amplifiers to prevent intermodulation from other RF sources.

4.1.7 Circuit Resonances

Susceptibility of equipment at any assembly level to electromagnetic interference shall be minimized by circuit designs which avoid resonances with undesired fundamentals, harmonics or products of known audio or radio frequency sources in the system complex.

Oscillations at frequencies apparently not related to design circuit resonances (commonly referred to as "parasitics") must be suppressed at their source, even though their presence may appear not to be detrimental. Such oscillations are usually unpredictable in magnitude and frequency and cannot be tolerated in operational equipment.

4.1.8 Government Furnished Equipment

It is assumed that any Government Furnished Equipment including Associate Contractor Furnished Equipment, supplied for incorporation into or use with the Dyna-Soar system complex has met the requirements of MIL-I-26600 and will not require further interference measurements. Certification of successful qualification under MIL-I-26600 should be required from the manufacturer of equipment in this category.

4.2 Airborne Equipment

4.2.1 **Bonding and Grounding**

4.2.1.1 Bonding and grounding within the aircraft shall be in accordance with MIL-B-5087A as a minimum requirement. Particular care shall be used to avoid joining or contact between dissimilar metals that would result in corrosion during atmospheric exposure or long term storage. This precaution is particularly applicable to antennae and structures in the immediate vicinity since the probability of existence of non-linear or rectifying junctions between dissimilar metals is high and the existence of non-linear junctions in the presence of high frequency fields will create spurious signals.

4.2.1.2 The airplane grounding system shall provide a separate ground bus or busses for signal circuits which shall each be grounded to structure at only one point. Power supplies for electronic circuits shall also be connected to structure only at this point.

By this method, signal circuits and power circuits will have no common impedance across which interfering signal voltages may be developed. So long as no signal currents are carried by the structure, relay coil grounds, chassis static grounds and grounds of other circuits not susceptible to interference, may be grounded to the basic structure.

These general directions are subject to change in situations involving the following conditions:

(a) The structure proper is bonded into a highly conductive extremely low impedance ground plane in which no magnitude of normal or transient current flow can produce interfering potential differences.

(b) The length of lead required to reach the signal ground bus is an appreciable fraction of a wavelength at the operating frequency of a strong interference source.

In either of the above cases, conservative design will dictate the careful determination of the ground circuit impedance and developed cross-coupling prior to final engineering release.

4.2.1.3 Neutral conductor of 1, 2 or 3 phase AC (locally supplied) power shall be grounded at only one point; that point shall be as near the source as possible. The structure shall not be used as the neutral conductor in any case.

4.2 **Shielding**

Wire shielding is defined as the covering of or the use of a covered wire, the covering consisting usually of braided conductors over the wire insulation; the total area of coverage normally in excess of 90% of the total wire insulation exterior area.

Spirally wrapped conductor shields are special types of wire shielding and shall not usually be considered for electrostatic

shields due to the large inductance per unit length.

Foil shielding is frequently advantageous from a space and weight standpoint but is comparatively fragile and inflexible.

Solid metal tubing may frequently be used to provide an extra-low impedance shield both in the electrostatic and electromagnetic modes with proper selection of material.

4.2.2.1 Wire shielding shall be used as a means of reducing interference pickup in low level, high impedance, circuits. Such shielding shall preferably be grounded at only one point, near the highest impedance or lowest voltage end, to prevent current flow in the shield due to the formation of a ground loop. In addition, shielding should not be continued into a shielding enclosure surrounding a pulse power source, power RF source or into a shielding enclosure surrounding a susceptible receiver or amplifier. In these instances, it is preferable to interrupt the shielding as shown in Figure 1b.

Wire shielding is also to be used to reduce radiation from wires carrying pulse or transient voltages where the wave fronts are sufficiently steep to produce radio frequency components in the wave. In most cases, a full metallic shield, foil or tubing rather than braid, is recommended to achieve more complete electrostatic shielding. Grounding at both ends and intermediate points is recommended, with careful avoidance of ground loop conditions.

High voltage, low current circuits may utilize shielded wire utilizing the shield as the return current path, with the shield isolated from ground except at source and sink.

4.2.2.2 The requirements for shield isolation and continuity of MIL-I-26600 paragraph 3.4, through pressure or hermetic seals shall be accomplished by use of an insulated extension of the shield connected through a pin, preferably adjacent, of the seal header or connector. The shield shall extend into the connector hood or shell and the shield tie-back distance shall be the minimum practical in all cases.

The hazards of ground loop creation as illustrated in Figure 1a shall be considered when entering into a shield enclosure about a source of RF or pulsed power or surrounding a sensitive amplifier. In these instances the method of Figure 1b is recommended.

4.2.2.3 Material used to shield high-power RF sources shall be sufficiently thick to attenuate radiation below the limits of MIL-I-26600, in accordance with the requirements of Ref. 1.1.1 and the appropriate model specifications. Required thickness of shielding material may be computed from the following:

$$\text{Attenuation (in db)} = 3.34T\sqrt{f\mu\sigma} + 10.82 + 10\log\frac{\sigma}{f\mu}$$

where

f = frequency in MC/sec.

μ = relative permeability of shield material.

σ = relative conductivity of shield material
T = material thickness in mils

4.2.3 Conductor Routing

4.2.3.1 Wires and other conductors shall be installed in the aircraft to provide minimum coupling by routing all AC power wiring separately from all other wiring. Deviation from this requirement shall be permitted only when it is necessary to include power wiring in a common connector, in a cable passing through a common structure, or when cables are required to cross other wiring. The design objective for spacing power from other circuits is maintenance of a two inch minimum separation. Space limitations frequently make such separations impractical, but full consideration should be given to obtaining the separation objective.

In most cases, wire routing is determined by a full scale mockup installation and attention given to maximum isolation in this phase of design will be rewarding in the final functional performance.

AC signal circuits may be routed with other wiring only if low level and adequately shielded. Sensitive signal circuits shall not be included in connectors or header groups together with high current AC circuits.

4.2.3.2 D-18306 shall be used as a guide by designers to determine appropriate conductor spacing and need for shielding and wire group twisting where audio (60 to 10,000 cps) frequencies are involved.

4.2.4 Wire Group Twisting

Twisting of wire groups shall be used as a means of reducing magnetic coupling and the interference created therefrom. The objective shall be to include in one twisted group the entire output (0° - 360°) of the AC source; i.e. a single phase (2 wire) system shall have both wires twisted; a 2 phase (3 or 4 wire) system shall have all wires twisted as a group; a 3 phase (3 or 4 wire) shall have all wires twisted as a group. The only exception to this direction shall be a 3 phase 4 wire system without phase unbalance, in which case the neutral (non-current-carrying) may be separately routed. Single phase drops from 3 phase 4 wire systems shall have line and neutral conductors twisted for the entire run. If one phase of a 3 phase 4 wire system is dropped in a cable run, the remaining wires shall be treated as single phase circuits, each twisted with its own neutral wire.

4.2.5 Selection of Wire Type

4.2.5.1 Selection of wire type for most effective reduction of interference transfer shall be in accordance with the following:

(a) Single phase AC circuits

shielded twisted pair cable with shield grounded to avoid ground loops shall be used for high voltage, low current circuits. Low voltage, high current circuits may use unshielded twisted pair or single conductor shielded with shield as return conductor; the latter only if the shield cross-section is adequate to carry the circuit current. Twisted pair is always preferred. If the high side wire must be routed separately from the return wire, the high side should be shielded and grounded in a manner to avoid ground loops.

In specifying twisted wire, the shortest practicable symmetrical lay consistent with the conductor physical characteristics shall be used.

(b) Three Phase AC Circuits

Provisions of the above paragraph shall apply, except substitute twisted triple for twisted pair.

4.2.6 Aircraft Antenna Design

Antenna systems on the airborne portions of the Dyna-Soar system shall be located so as to minimize cross-coupling and interaction so far as is practicable consistent with pattern and structure considerations. All antennas shall be designed to utilize a shielded coupler/antenna-cover whenever possible during ground testing to minimize interference with and from other services.

Coupling between antennas shall be measured at the transmitter/receiver terminal points with all multiplexing and coupling systems in normal configuration, properly terminated, and tuned to operating frequencies. The magnitude of cross-coupling shall be assessed for deleterious effect on equipment operation. Test methods are outlined in Section 5.

4.3 Ground Support Equipment

4.3.1 General Practices

4.3.1.1 It is assumed that the provisions of ARDC Manuals 80-5 and 80-6 will be used as a guide for ground support equipment design.

4.3.1.2 The General Practices of Section 4.1 of this document shall apply to Ground support equipment for the Dyna-Soar program.

4.3.2 Such shielding, filtering and other suppression measures shall be taken as are required to assure compliance with MIL-I-26600 in accordance with the requirement of Reference 1.1.1.

4.4 Communication and Control Equipment

(See Section 4.3, this document for interim information.)

5.0 TEST PLANNING

5.1 General

5.1.1 Interference Control Tests

Each item of equipment considered to be susceptible to or capable of generating radio interference shall be tested to determine the level and character of susceptibility or generated interference. These tests shall be conducted to the requirements of the appropriate classification delineated in MIL-I-26600.

5.1.2 Interference Compatibility Tests

Interference Compatibility Tests will be conducted in accordance with Sections 5.2 through 5.5 of this document.

5.1.3 Friendly Interference Tests

In addition to the tests noted in 5.1.1 and 5.1.2 above, the communication and control receiving equipment shall be tested for reliable performance in the signal density environment predicted by studies.

5.1.3.1 Signal Simulation Equipment capable of producing the signal density environment of 5.1.3 will be designed and fabricated to perform these tests.

5.2 Airborne Equipment Tests

Testing of installed equipment comprising aircraft systems and subsystems will be performed to determine the degree of compliance with MIL-I-26600, Class Ib.

5.2.1 Each flight configuration will be subjected to pre-flight RF compatibility testing with each receiver operating at normal frequency and sensitivity, each RF and pulse source operating at full power and with antenna covers removed. Receiver outputs shall be examined for amplitude of unwanted signals under these conditions, and evaluated for the effect of any interference detected.

5.3 Ground Support Equipment Tests

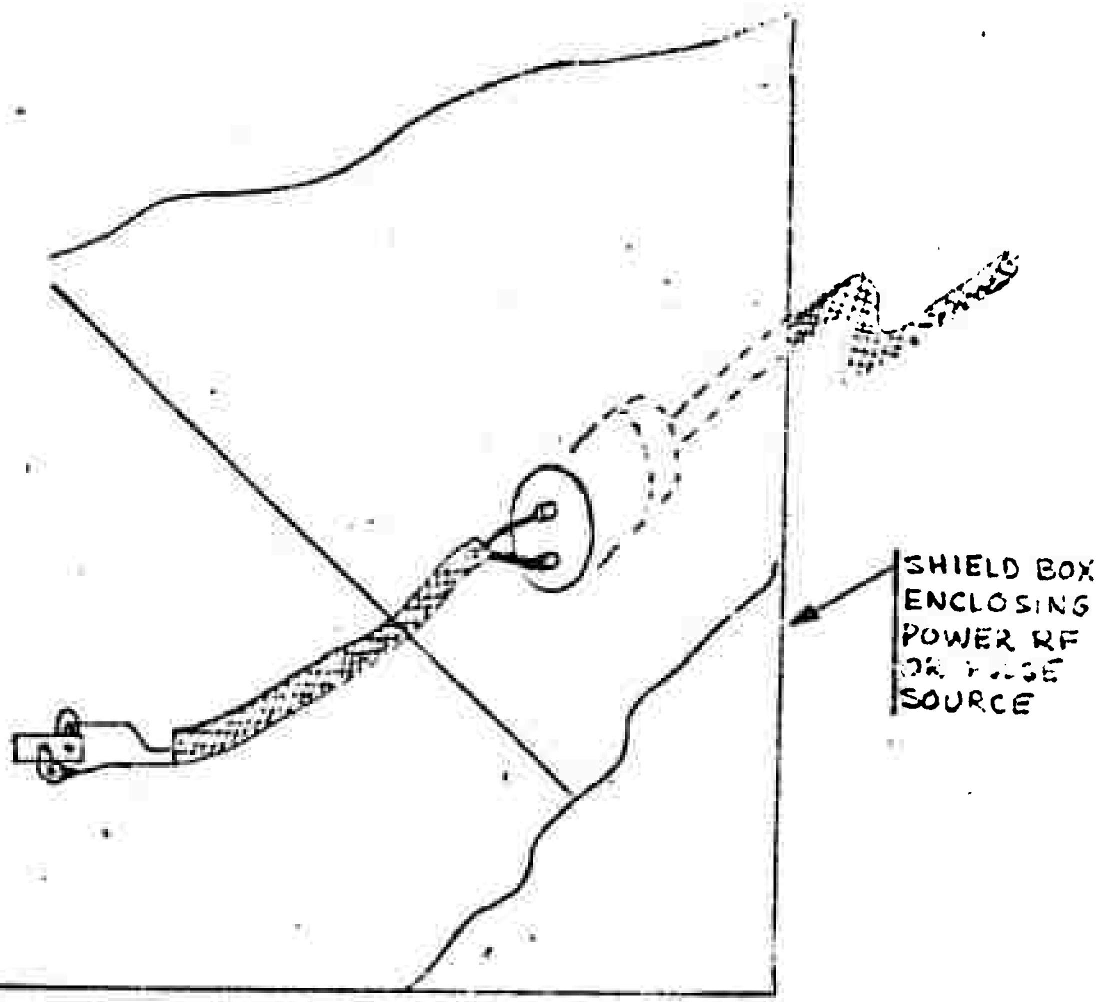
Testing of ground support equipment, excluding communication and control equipment, will be performed to determine the degree of compliance with MIL-I-26600, Class Ib or Class III, as applicable.

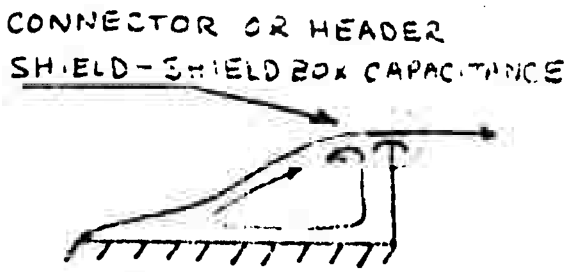
5.4 Communication and Control Equipment Tests

Testing of communication and control equipment will be performed to determine the degree of compliance with MIL-I-26600 Class II or Class III as applicable.

5.5 Base Facility Testing

Base facilities installed or made available for Dyna-Soar operations will be tested to determine the degree of compliance with MIL-I-26600, Class III and Class IV, as applicable. A summary of Base interference levels from other than Dyna-Soar facilities shall be made to insure that no interference exists or will exist during launching operations.





EQUIVALENT SCHEMATIC OF SHIELD CIRCUIT, SHOWING GROUND LOOP

Fig. 1a

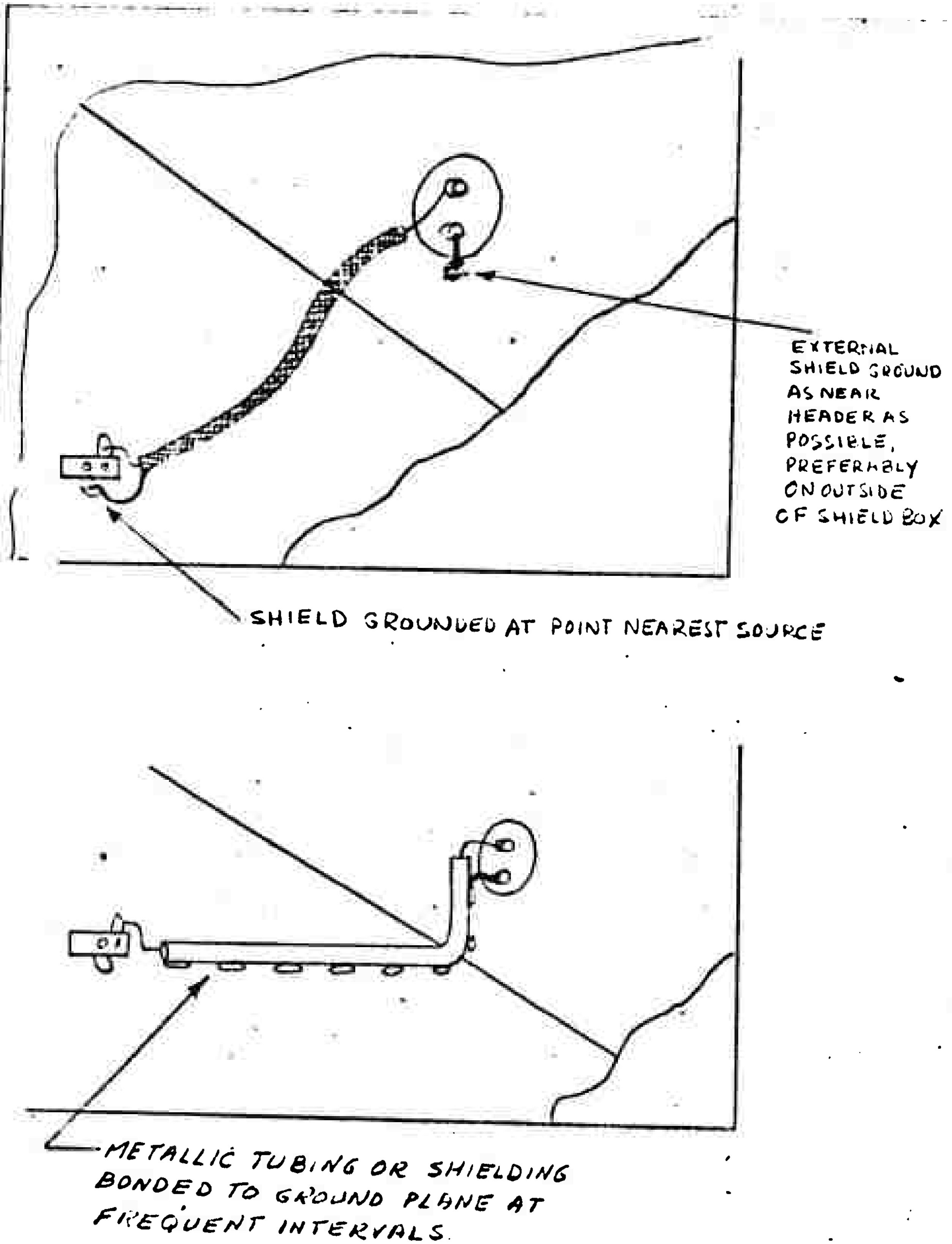

EXTERNAL SHIELD GROUND AS NEAR HEADER AS POSSIBLE, PREFERABLY ON OUTSIDE OF SHIELD BOX
SHIELD GROUNDED AT POINT NEAREST SOURCE
METALLIC TUBING OR SHIELDING BONDED TO GROUND PLANE AT FREQUENT INTERVALS

FIG. 1b